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RESEARCH ARTICLE / ARAŞTIRMA MAKALESI

Determination of the Abrasion Resistance of Upholstery Fabrics Used in Office Chairs Having a Massage Mechanism

Masaj Mekanizmalı Ofis Koltuklarında Kullanılan Döşemelik Kumaşların Aşınma Direncinin Belirlenmesi

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Abstract

Various studies in the literature examine the disorders and productivity losses experienced by office workers. An office chair having a massage mechanism is also designed to prevent these disorders and to increase the comfort of office workers. The rubbing movement of the massage mechanisms causes abrasion on the surface of upholstery materials over time. Hence, the selection of upholstery materials to be used in office chairs having massage mechanisms is important. In this study, upholstery materials that are used in office chairs having massage mechanisms have been investigated. As a contribution, spacer fabrics have been used by combining with office chairs having the massage mechanism. Furthermore, the abrasion resistance of 4 different spacer fabrics has been measured and compared with the materials used in the market. In addition to the abrasion resistance test, the air permeability test has been carried out to investigate the breathability of upholstery materials. We have found that the abrasion resistance of leather, artificial leather, and spacer fabrics is superior to other fabrics' abrasion resistance. The results reveal that spacer fabrics have better breathability than any other material.

Keywords: *Office Chair, Textile Materials, Taber Test, Massage Mechanism, Upholstery*

Öz

Literatürde ofis çalışanlarının yaşadığı rahatsızlıkları ve verimlilik kayıplarını inceleyen çeşitli çalışmalar bulunmaktadır. Bu rahatsızlıkların önüne geçmek ve ofis çalışanlarının konforunu arttırmak amacıyla masaj mekanizması içeren bir ofis sandalyesi tasarlanmıştır. Masaj mekanizmalarının sürtünme hareketi zamanla döşeme malzemelerinin yüzeyinde aşınmaya neden olur. Bu nedenle masaj mekanizmalı ofis koltuklarında kullanılacak döşeme malzemelerinin seçimi önemlidir. Bu çalışmada masaj mekanizmalı ofis koltuklarında kullanılan döşeme malzemeleri incelenmiştir. Ek olarak spacer kumaşların masaj mekanizmalı ofis koltuklarında döşeme malzemesi olarak kullanımı incelenmiştir. Ayrıca 4 farklı spacer kumaşın aşınma direnci ölçülmüş ve piyasada kullanılan malzemelerle karşılaştırılmıştır. Döşeme malzemelerinin nefes alabilirliğini araştırmak amacıyla aşınma direnci testinin yanı sıra hava geçirgenlik testi de yapılmıştır. Deri, suni deri ve spacer kumaşların aşınma direncinin diğer kumaşların aşınma direncinden üstün olduğunu tespit edilmiştir. Sonuçlar, spacer kumaşların diğer tüm malzemelerden daha iyi nefes alabilirliğe sahip olduğunu ortaya koymuştur.

Anahtar Kelimeler: *Ofis Koltuğu, Tekstil Malzemeleri, Taber Testi, Masaj Mekanizması, Döşeme*

1. Introduction

Nowadays, workplace safety, working conditions, and the health of workers have drawn attention. Especially, people who work with computers during office hours have occupational disorders [1,2]. Repetitive static movements, muscle loads, and unfavorable body positions are the main reasons for occupational disorders. Moreover, office equipment such as non-ergonomic office chairs can also cause these disorders. Therefore, scientists have improved working equipment such as ergonomic office chairs.

The most disturbed body parts in office workers are neck, shoulder and lower back [1, 2, 3, 4]. In a recent study, Çetin et al. have conducted a survey by collecting the complaints of the 382 office workers randomly selected from Dokuz Eylül University academic and administrative staff who are sitting for a long time. In their study, the regions where office workers have been very uncomfortable are 85.45% waist, 81.36% neck, 79.65% lower back, 78.85% upper back, 76.54% shoulder, and 73.20% coccyx. Based on the survey results, they have proposed two different electromechanical systems capable of two different massage types (kneading and vibration) that have been designed to reduce the pain of the shoulder and upper back region. These systems have been integrated into a developed new office chair prototype, consisting of three separate parts such as the waist, back, and neck that can be adjusted independently from each other (Figure 1) [5]. The mechanism making a kneading motion consists basically of cams and wheels as Figure 1 depicts. In addition, the expectations of office workers from their chairs were

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investigated by applying a survey in the study of Çetin et al. According to the survey the office workers have complaints of sweating due to the chair and they expect a chair covered with antiperspirant fabrics (with high air permeability). Finally, it is important to reduce the occupational diseases that may occur in office workers and to increase their physiological comfort to the examples in literatures.

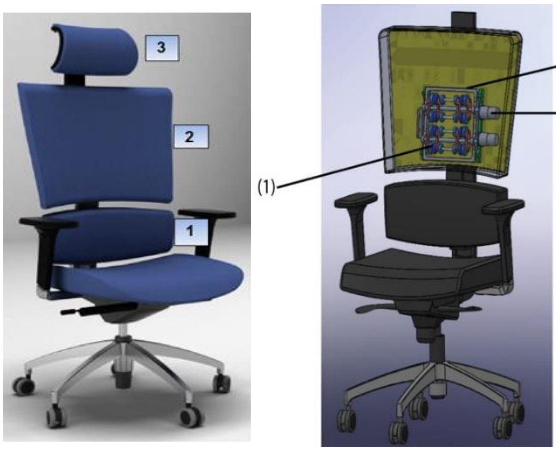


Figure 1. a. Office chair designed in the scope of San-Tez Project (1: Waist, 2: Back, 3: Neck) b. The office chair with a kneading massage mechanism (1: Massage wheels, 2: Mechanism body, 3: Electric motor) [5].

There are chairs having commercial massage mechanisms in the market. However, these chairs are not suitable to use in the offices. The commercial massage chairs are bulky, stationary, and require a permanent electrical connection. Unlike these commercial chairs, M. Çetin et al.'s design contains massage mechanisms that are lightweight, mobile, and work with a battery. Although Çetin et al. [5] have designed the office chair having a kneading massage mechanism, they have not investigated the effects of the massage mechanism on the upholstery materials which are covered on the chair.

In this study, upholstery materials used in the back area of the office chair where the massage mechanisms can cause abrasion are examined. In this chair design, abrasion motion that can cause abrasion on upholstery materials is simulated in Figure 2.

The length of sitting time covers more than half of the working time of office workers. Solutions must be produced to increase the comfort of office workers who sit for long periods. Accordingly, in order to increase the comfort of the office workers, it is also necessary to reduce sweating complaints. So, it should be used upholsteries that have high air permeability on the office chairs. In this study, in addition to abrasion resistance, air permeability is measured to determine the breathability of upholstery materials. The spacer fabrics have been suggested as an alternative to upholstery materials used in the market. No information was found about the spacer fabrics, used for this purpose, in previous studies in the literature. In this study, their performances are compared with upholstery materials on the market.

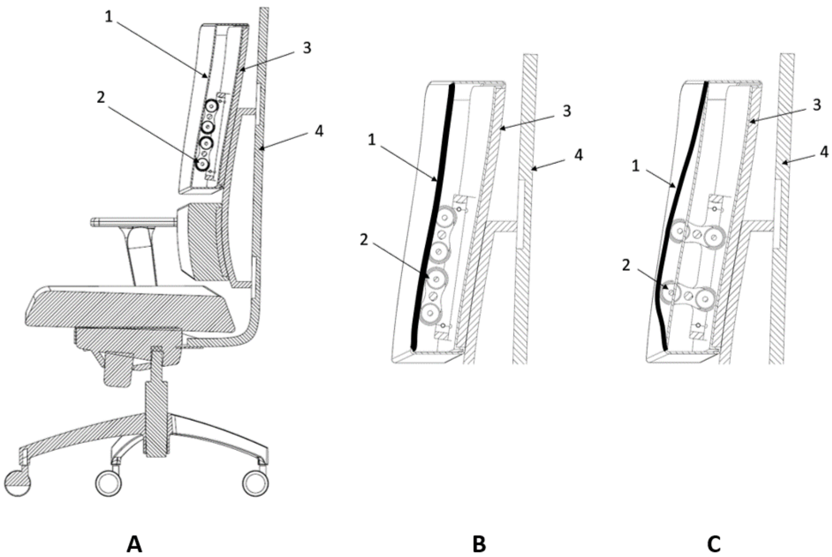


Figure 2. A. Cross Section of the office chair designed in the scope of San-Tez Project (1: Upholstery fabric, 2: Wheels of the kneading massage mechanism, 3: Chair's upper back frame, 4: Backrest carrier mechanism of the chair) B. Neutral position of the kneading massage mechanism, C. The position of the kneading massage mechanism in contact with the upholstery material.

2. Materials and Methods

The eight types of upholsteries consisting of a leather, an artificial leather and six different upholstery fabrics have been supplied from the market. Additionally, the four types of spacer fabrics, which have not been used in office chairs before, have been supplied (Table 1). Air permeability and abrasion resistance tests have been applied to these supplied materials and compared with each other. These testing were done after conditioning (for 24 hours) of material and in standard atmospheric conditions (20 ºC ± 2 temperature and 65% ± 4 relative moisture).

All fabrics in the study were tested for use as a single layer upholstery fabric in the upper back area of the chair, in front of the massage mechanism. The abrasion test was applied to the back surfaces of the fabrics that would contact the mechanism. The air permeability test, on the other hand, was applied to the upper surfaces of the fabrics that would contact the upper back area of the user's body.

Table 1. Properties of the fabrics tested.

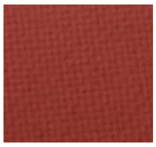
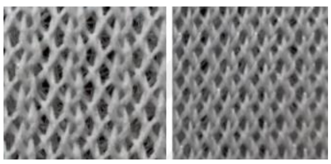
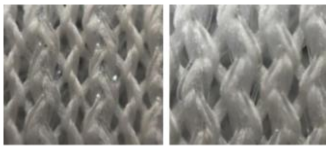
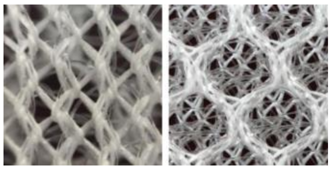
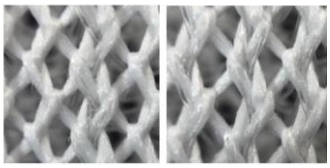
Sample Number	Materials	Properties	Surface Images
1	Mesh Fabric	100% PES ~ 1 mm Thick	
2	Flat Knit Fabric	100% PES ~ 2 mm Thick	
3	Plain Weave Fabric	30% Wool, 70% Polypropylene ~ 1.5 mm Thick	
4	Panama Weave Fabric	100% Perfentex Plus ~ 2 mm Thick	
5	Crepe Knit Fabric	100% Recycled PES ~ 2 mm Thick Metal-Free Dye Material	
6	Satin Weave Fabric	100% Pure New Wool ~ 1.5 mm Thick Metal-Free Dye Material	
7	Artificial Leather	2% PU, 80% PVC, 18% PES ~ 0.8 mm Thick Polyurethane and polyvinyl chloride mixture coated Masterbatch pigment dyed The floor,100% PES knitted lining	
8	Natural Leather	Cowhide leather ~ 0.9 mm Thick Chrome tanned Water-based finish applied Pigment dyed	
9	Warp Knitted Spacer Fabric	100% PES ~ 9 mm Thick Two Sides Closed Structure Mesh density*: 8/6	

Table 1 (Continued)

10	Warp Knitted Spacer Fabric	100% PES ~ 10.6 mm Thick Two Sides Closed Structure Mesh Density*: 5.5/4	
11	Warp Knitted Spacer Fabric	100% PES ~ 5 mm Thick One Face Open and The Other Face Closed Structure Mesh Density*: 6.25/4	
12	Warp Knitted Spacer Fabric	100% PES ~ 7 mm Thick Two Sides Closed Structure Mesh Density*: 7/5	

* Mesh density describes the number of course over wales per cm

Abrasion resistance test is used to quantify the normal usage duration of upholstery materials. In the literature, there are several devices to determine the abrasion resistance of upholstery materials such as Stoll Abrasion Tester11, TABER® Rotary Platform Abrasion Tester (which measures structural abrasion resistance) [6,10-15], Nu-Martindale Abrasion and Pilling Tester (which measures aesthetic abrasion resistance) [6,8,9,11-18], Schopper Abrasion Tester[6,15,17], Cesconi Abrasion Tester [13], Flex Abrasion Testing Machine [7].

Taber 5155 friction test device has the most similar abrasion process between the upholstery materials in the office chair and the discs of the massage mechanism (manufactured from Delrin 2700 NC010). Therefore, we have used Taber 5155 friction test device for the abrasion resistance test in our study. The evaluation process has been carried out under ASTM D 3884-09 [19].

In addition to the abrasion resistance tests, we have investigated the air permeability of upholstery materials. Therefore, air permeability is closely related to the thermophysiological comfort of the materials.

For the air permeability test, a Textest FX 3300 Air Permeability Tester III has been used in our study. The air permeability measurement has been carried out according to TS 391 EN ISO 9237 standard [20], under the pressure of 200 Pa and 10 repetitions using an apparatus with a 20 cm2 area.

3. Results and Dicussion

In the study, taber test with 3 repetitions and air permeability test with 10 repetitions were applied to all fabrics. ANOVA test (α = 0.05) was applied to the results to determine the differences in abrasion and air permeability properties of the fabrics. When the taber test results in Table 2 are examined; Since no abrasion was observed in the samples 7, 8, 9, 10 and 12, the abrasion values for these fabrics were taken as 0 while performing the ANOVA test. When the air permeability results seen in Table 2 are examined; Since the air permeability (due to its very porous structure) value could not be recorded in the 12th sample, this fabric was neglected and ANOVA test was applied. The results of the abrasion resistance and air permeability tests applied to spacer fabrics, and upholstery materials are given in Table 2. The abrasions on upholstery materials after the Taber tests are illustrated in Figure 3.

Table 2. Results of Taber and air permeability tests.

Sample Number	The number of cycles for which abrasion began (Cycle)	Air permeability (Litres per square meter per second: l /m²/sec.)
1	221.43	3182.00
2	98.80	795.70
3	715.48	698.00
4	779.76	760.90
5	282.14	583.60
6	357.14	475.60
7	No abrasion or disintegration has been observed during the test period. Only staining on the surface has been observed.	4.40
8	No abrasion or disintegration has been observed during the test period. Only a temporary change in direction of the pile has been observed.	0
9	No abrasion or disintegration has been observed during the test period. Only staining on the surface has been observed.	4332.00

Table 2 (Continued)

10	No abrasion or disintegration has been observed during the test period. Only staining on the surface has been observed.	3804.00
11	At 558.33 cycles surface abrasion began.	6841.00
12	No abrasion or disintegration has been observed during the test period. Only staining on the surface has been observed.	Due to the large porous structure of this fabric, the air permeability is too much to record any value with the device.

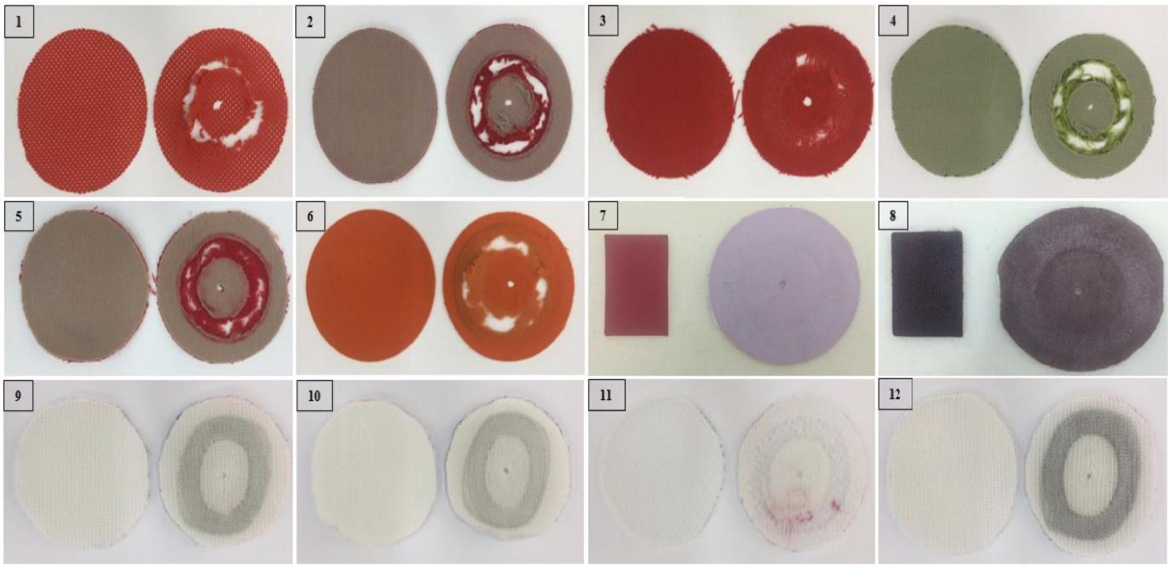


Figure 3. Surface Images of Before and After Abrasion Test of the Materials between 1 to 12 (after 2000 cycles).

According to the results of the ANOVA test performed on the air permeability data, it is seen that F: 2197.68 > Fcritical: 1.93 (between groups). From this, it was concluded that the air permeability values of the tested fabrics are different. The results indicate that the air permeability of the materials is listed 12, 11, 9, 10, 1, 2, 4, 3, 5, 6, 7, and 8 in descending order. Artificial Leather (8th sample) has the worst air permeability value (0 l /m2/sec.) among the materials (Table 2).

When Table 2 is examined, it is seen that the air permeability values increase as the surface porosity increases as expected. In addition, the air permeability of spacer fabrics varies depending on the surface structure (such as one face open and the other face closed, two sides closed) and the mesh density. For spacer fabrics other than material 12 (materials 9, 10, and 11), it can be interpreted that as the thickness of the material increases, the air permeability decreases. It is seen that material 11 has a higher air permeability value than materials 9 and 10. By reason of it is both thinner than material 9 and 10, and has one face open and the other face closed structure.

Although material 12 is not the thinnest spacer fabric, it has a higher air permeability value than the others. Despite material 12 is thicker and two sides closed structure, it has higher air permeability due to its lower mesh density when it is compared to material 11.

By examining the air permeability values of other upholstery materials, it is seen that material 1 has the highest value after spacer fabrics' values. Owing to the mesh fabric has a more porous structure like spacer fabrics.

It is known that materials 2, 3, 4, and 5 are not as porous as spacer fabrics and material 1. The air permeability value of these fabrics is affected by altering the width of the pores which depends on the knitting structure.

It is observed that materials 7 and 8 have the lowest porosity among upholstery materials. The differences in air permeability of these materials are based on too many parameters such as thickness, chemical treatments, and the structure of bottom surfaces.

The evaluation process of the abrasion resistance test has been carried out by taking into account the number of cycles in which abrasion (specimen rupture or appearance of a hole) occurs in the material surface. Abrasion test has been continued for 2000 cycles (1680 sec) with the Taber device. According to the results of the ANOVA test performed on the abrasion resistance data of the materials, it is seen that F: 1707540 > Fcritical: 2.22 (between groups). Hence, it was decided that the abrasion resistance values of the tested fabrics are different.

During the test process, abrasion has not been observed in 7, 8, 9, 10, and 12 materials. Hence these materials have the best abrasion resistance as seen in Table 2. There is only staining on the surface for materials 8, 9, 10, and 12 after 2000 cycles. At the end of the test, only a temporary change in direction of the pile has been observed in material 7.

We have observed that the surfaces of materials 1, 2, 3, 4, 5, 6, and 11 have begun abrasion after specific cycles of Taber. Referring to Table 2, abrasion on material 4 has started after 779.76 cycles. When we compare the number of cycles for which abrasion began on the surface of materials, we have seen that material 4 is followed by 3 (715.48 cycles), 11 (558.33 cycles), 6 (357.14 cycles), 5 (282.14 cycles), 1 (221.43 cycles), and 2 (98.8 cycles), respectively.

The results obtained from abrasion resistance tests for all materials used in this study are interpreted according to the following assumption:

The massage mechanisms' wheels, which have a smoother surface than the abrasive wheels of the Taber device, cause less abrasion on the surface of the upholstery materials.

According to this assumption, materials with no abrasion on their surface for 2000 cycles in the Taber device withstand the abrasion of the massage mechanism for much more cycles. Even if the abrasion action of the Taber device is the same as the massage mechanism, it exposes the materials to very intense abrasion since the wheels are made of grindstone. However, although the wheels of the massage mechanism are made of a hard material, their surfaces are smooth.

The high air permeability of the upholstery materials used in the office chair will reduce the amount of sweating of the office workers and will increase the comfort. The designed massage mechanism also aims to increase the comfort of office workers. In order to provide these two comfort-enhancing elements together, upholstery material with high abrasion resistance and air permeability should be selected. From this point of view, and based on the test results in the study, it is seen that the 12th upholstery material (air permeability: too much to record any value and abrasion resistance: abrasion or disintegration has been observed) provides the best for both elements. However, in order to feel the massage effect, the thinness of the upholstery material should also be high. Therefore, it is concluded that the 9th upholstery material provides optimum properties in terms of thinness, air permeability (4332.00 l /m2/s) and abrasion resistance (no abrasion or disintegration has been observed).

4. Conclusions

Abrasion resistance is one of the most important properties of the upholstery materials of office chairs. The high abrasion resistance of upholstery materials extends office chairs' lifetime. Since the office chair is one of the crucial pieces of equipment for the physiological and psychological comfort of an office worker, it is expected that the upholstery materials have high air permeability.

In this study, there has not been any abrasion after 2000 cycles for leather, artificial leather and spacer fabrics. Moreover, upholstery fabrics have abrasion after 221.43, 98.8, 715.48, 779.76, 282.14 and 357.14 cycles. It is found that the abrasion resistance of leather, artificial leather and spacer fabrics are higher than upholstery fabrics. When upholstery fabrics are compared among themselves; it is concluded that the abrasion resistance and air permeability values of the material 4 (100% Perfentex Plus Fabric), 3 (30% Wool, 70% Polypropylene Fabric), and 6 100% Pure New Wool) are acceptable. It was found that the air permeability values of upholstery materials other than spacer fabrics are not satisfactory.

As a result of this study, it has been determined that spacer fabrics, which are thought to be an alternative to upholstery materials used in office chairs, performed better than other materials in terms of abrasion resistance and air permeability.

The tests and evaluations in this study were made for the case of using a single layer of upholstery fabric in front of the massage mechanism. However, these results may vary if more than one layer is used on top of each other or in combination with other materials.

Investigating the air permeability and abrasion resistance properties of the upholstery materials lead us to design very comfortable office chairs. This study is one of the initial steps taken in this direction.

This study evaluated to the thinness (to feel the effect of the massage), air permeability (to reduce perspiration) and abrasion resistance properties of the upholstery materials used or to be used in the office chair with massage mechanism. In future studies, a layered backrest design can be investigated so that users do not feel the massage mechanism (when the massage mechanism is not working) when leaning against the back of the chair. In order to evaluate the filling materials that can be used between the upholstery material and the massage mechanism, in addition to the objective test methods, an experimental plan supported by subjective evaluations (including user experience) will bring the researchers to the most successful result.

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Author Contribution Statement

The authors declare no conflict of interest. Author contributions are as follows:

Münire Sibel ÇETİN: Writing - Original draft, Performing and evaluating tests, Validation, Resources, Investigation, Conceptualization. Olgun ALTAY: Design of massage mechanism & Writing. Hasan ÖZTÜRK: Design of massage mechanism. Review & Editing, Supervision. Gülseren KARABAY: Review & Editing. Gülseren KURUMER: Writing - Review & Editing, Supervision.

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